

## THE MOLLUSCAN FISHERIES

The San Francisco Bay Area undoubtedly possesses the greatest potential of any area in the State for shell-fish culture. Ironically, however, clam and oyster fisheries which at one time flourished and were the most valuable in the State, have waned until at the present time clams rarely are taken commercially and oyster culture has largely been abandoned in favor of other more suitable areas.

Packard (1918) described the molluscs in the most detailed investigation ever made of the bottom fauna of San Francisco Bay. His work was part of the U. S. Fish Commission's investigation undertaken during the presence of the U. S. Fisheries Steamer "Albatross" on the Pacific Coast in 1912 and 1913.

The ensuing material (from Packard) will serve to show the relative distribution as well as the more common species of mollusks in the Bay Area:

"The fauna from San Francisco Bay comprises 81 species and varieties, 43 of which are pelecypods, 31 gastropods, and 7 chitons.

"Fifty-nine percent of the species listed below were taken exclusively within San Francisco Bay. This percentage would be somewhat decreased had collections been made along the littoral outside the Golden Gate. Nevertheless the relatively small percentage of forms common to the two contiguous regions is noteworthy. A number of the forms listed below were rarely taken. Such species obviously have little significance in such a study. Therefore, it has seemed advantageous to prepare a list of the more common species.

"The more common or prevalent species may arbitrarily be defined as those that were taken at one-fourth or more of the stations of any given group of stations, as suggested by Sumner et al. (1913, p. 69). In Table [32] the prevalent species for the different divisions of San Francisco Bay are given."

Appendix D contains a list of selected mollusks of the San Francisco Bay Area.

### THE OYSTER FISHERY

#### Early History

Historically, the native oyster (*Ostrea lurida*), was present in the Bay in prodigious quantities and clams and mussels were plentiful. Townsend (1893) one of the foremost experts of the time on oyster culture, who was sent by the U. S. Fish Commission to make a survey of the oyster fisheries on this coast, reported the following: "There are extensive deposits of this species [native oyster] in the shallow water all along the western part of the Bay, and their dead shells washed ashore by the high seas that accompany the

strong winds of the winter season, have formed a white glistening beach that extends from San Mateo for a dozen or more miles southward. So abundant are they that this constantly increasing deposit of shells covers everything along shore and forms bars extending into the Bay.

"Schooners frequently carry away loads of them for the making of garden walks and for other purposes to which oyster shells are adapted. The supply is unending."

TABLE 32  
PREVALENT MOLLUSCAN SPECIES IN SAN FRANCISCO BAY—1912-1913<sup>1</sup>

Species	San Pablo Bay	South San Francisco Bay	North San Francisco Bay	Entire Bay (quantitative) hauls
<i>Cordium corbis</i> [ <i>Clinocordium nuttalli</i> ] <sup>2</sup>	—	x	x	x
<i>Macoma balthica</i> [ <i>Macoma inconspicua</i> ]	x	—	—	—
<i>Macoma inquinata</i> [ <i>Macoma irus</i> ]	—	—	x	x
<i>Macoma nasuta</i>	x	x	x	x
<i>Mya arenaria</i>	x	x	—	—
<i>Mya californica</i> [ <i>Cryptomya californica</i> ]	x	x	x	x
<i>Mytilus edulis</i>	x	—	x	x
<i>Ostrea lurida</i>	—	x	x	x
<i>Protothaca staminea</i>	—	—	x	—
<i>Schizothaerus nuttalli</i>	—	—	x	—
<i>Thais lamellosa</i>	—	—	x	x
<i>Zirfea gabbi</i> [ <i>Zirfea pilsbryi</i> ]	—	—	x	x

<sup>1</sup> After Packard (1918).

<sup>2</sup> Scientific names in brackets differ from original publication to conform with the latest taxonomic works.

Current testimony to the existence of these tremendous deposits is found in the recent book *San Francisco Bay* by Harold Gilliam, Doubleday and Company, New York: "The Bay is one of the few places in the world where cement is made from shells and possibly the only place where the shells and the mud exist naturally in almost exactly the right proportions for cement making.

"For more than a quarter of a century this [cement] plant has been fed by the remains of the Bay's ancient oyster populations and it is estimated that the Bay floor is covered with enough shells to continue the operation another 50 years."

Bonnot (1935), who was assigned to the State's oyster investigations in the 1930's, gave the following brief history of the oyster industry from 1870 onward:

"An historical account of the oyster industry of California must deal almost entirely with exotic species. The native oyster has been utilized commercially since the days of the Spaniards but no worthwhile attempt at any form of culture was ever made. The natives were merely taken from the natural beds until the introduction of other and larger species thrust them into the background.

"In recent years the sale of oysters in California has been confined to eastern oysters (*Ostrea virginica*)

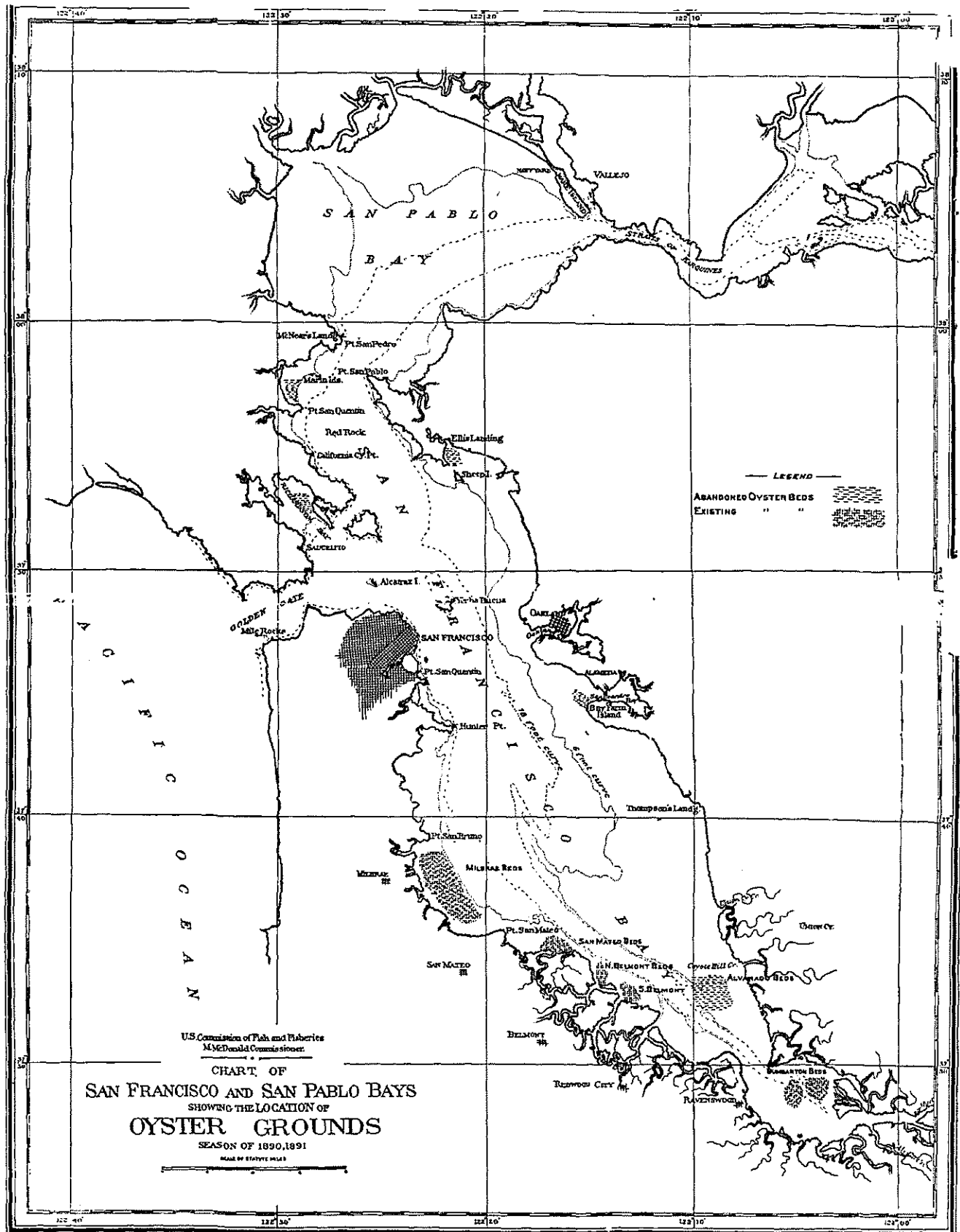


FIGURE 32. Map of Oyster Grounds, 1890-1891.

[now *Crassostrea virginica*], shipped market-size and held in San Francisco or Tomales bays, and to Olympia oysters [*Ostrea lurida*] shipped from the state of Washington. There is no particular reason why the California native oyster could not compete favorably with Olympias except that in both California and Washington the old-time oysterman, until very recently, clung to the trial and error method of culture, and natural conditions in the State of Washington have been such that these methods were effective there.

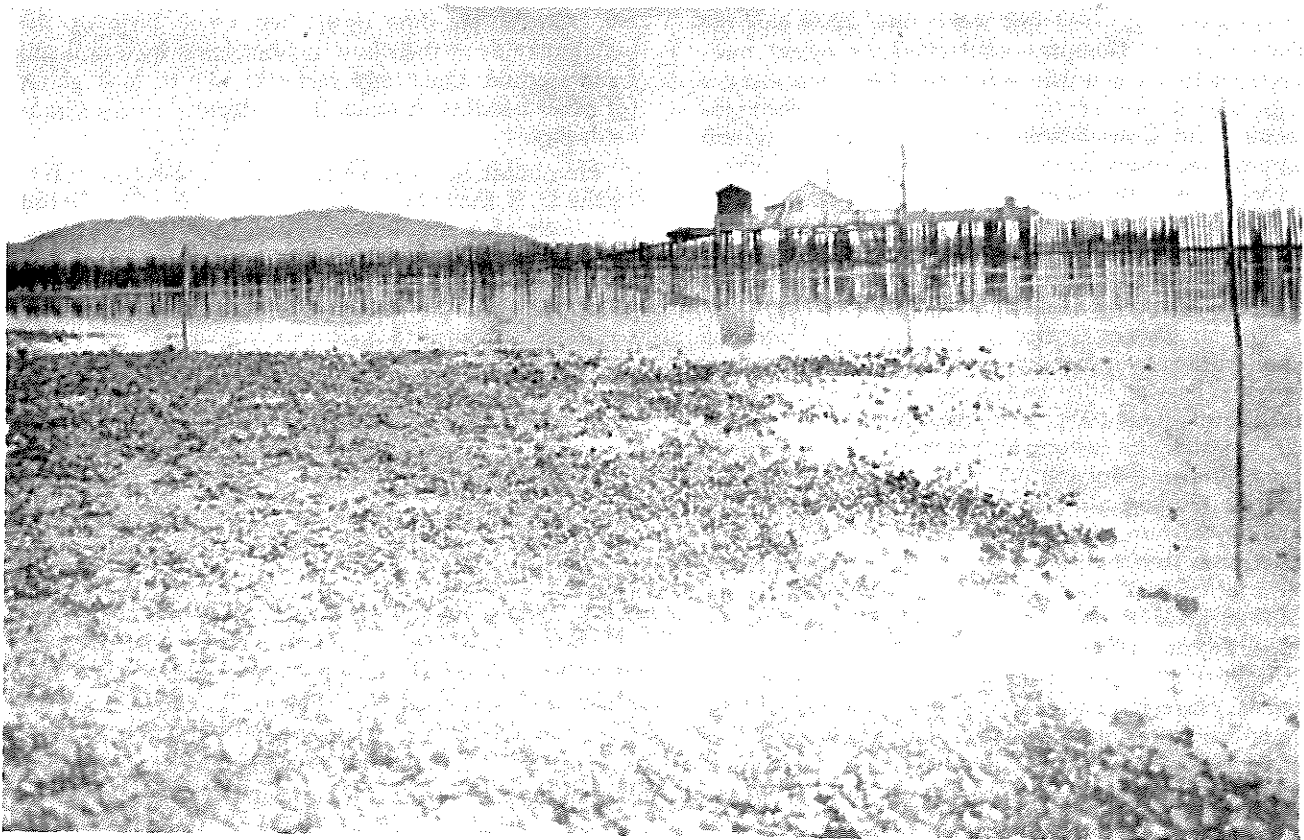
"The first introduction of a foreign oyster on a commercial scale was in 1868 when the Mexican Oyster Company started importing Mexican oysters [*Ostrea iridescentis* or *chilensis*] to San Francisco from Altata and Acapulco. The oysters were shipped by steamer and sold at the dock for 25 cents each. A notice was posted several days in advance of the steamer's arrival. This business was not very profitable as many of the oysters died during the trip and in 1870, when the eastern oysters began to be shipped to San Francisco on the newly completed transcontinental railroad, the Mexican company went out of business. Mexican oysters were again imported during 1897-99 by Eli Gordon, of San Francisco but the conditions arising from the Spanish-American War caused him to discontinue the business.

"During 1870 [according to Collins (1892) this oyster shipment came West in 1869] A. Booth [and

Company] of Chicago shipped three carloads of eastern oysters to San Francisco. Most of these were sold at once and those remaining were laid out in the bay. Booth sold out to the Morgan Oyster Company in 1871 and passed from the picture.

"The first oyster beds were located at Sausalito, Point San Quentin, Sheep Island [Brooks Island], Oakland Creek and Alameda Creek. These beds were soon abandoned and by 1875 all the beds were located in South San Francisco Bay. In 1872 Corville and Company laid out a bed just south of Point San Bruno. After operating here for several years they sold to Swanberg and West who worked the ground until 1885 when it was absorbed by the Morgan Oyster Company. In 1884 Doane and Company established a bed at North Belmont and the next year sold it to Morgan Oyster Company. In 1877 M. B. Moraghan made a start in the oyster business and controlled several beds, the most important being at Coyote Point, near the Morgan Oyster Company bed. By 1885 we find only two companies engaged in the oyster business; Moraghan with two or three beds and the Morgan Oyster Company controlling six. The Morgan Oyster Company beds at this time were located at Dumbarton, San Bruno, Millbrae, Alvarado, North Belmont, and South Belmont. The Alvarado station was abandoned in 1890 as it was too exposed to strong winds and heavy seas.

FIGURE 33. Moraghan Oyster Establishment 1890. Note the enclosed bed and thickness of the oysters which are exposed at low tide. Photo credit. Report U.S. Commission of Fish and Fisheries for 1889-1891.



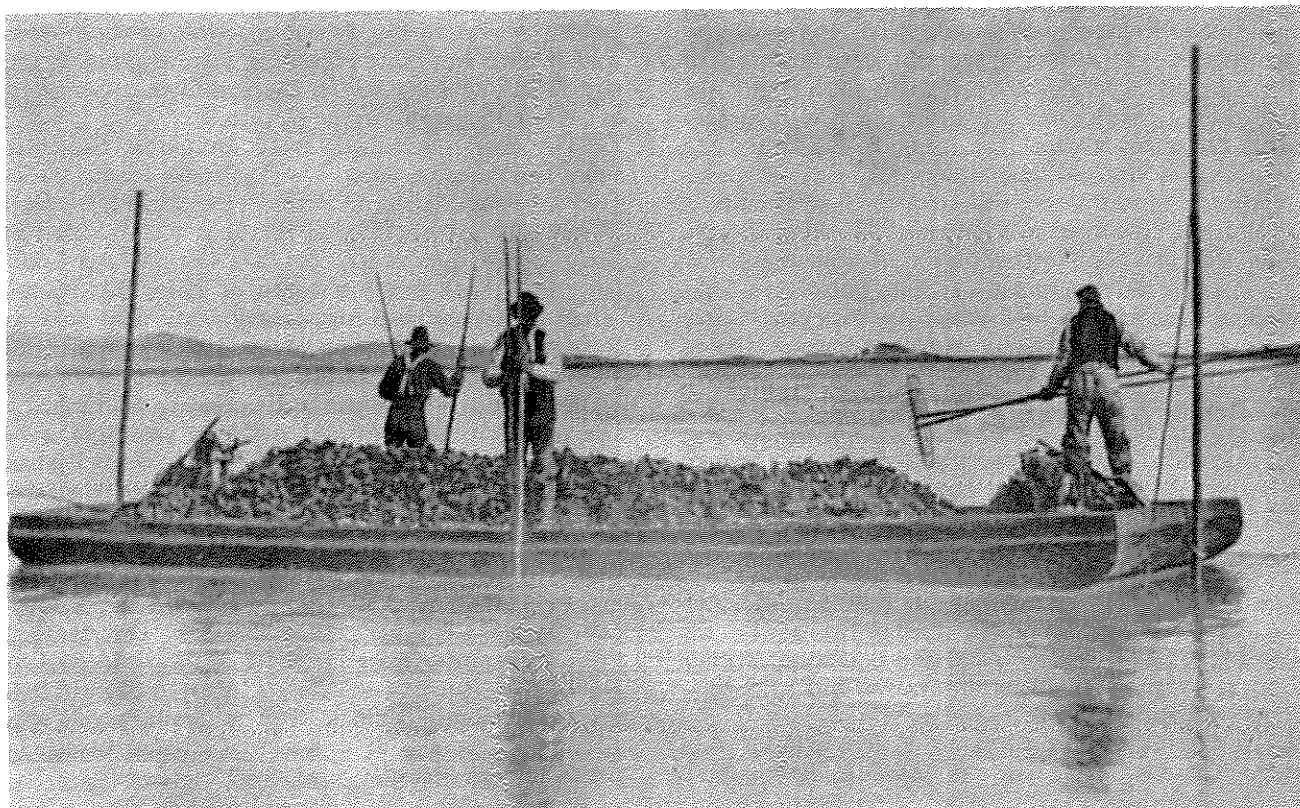


FIGURE 34. Tonging oysters in South San Francisco Bay 1890. Photo credit. Report U.S. Commission of Fish and Fisheries 1889-1891.

"Moraghan dropped out some time later and the Morgan Oyster Company controlled the oyster business until 1921 when they went out of business and the Consolidated Oyster Company took over their interests. The Consolidated Oyster Company is still carrying on, maintaining until 1929 the old Millbrae bed which was started by Morgan Oyster Company in 1874, and now operating a bed at Oyster Point.

"The first oysters shipped by Booth in 1870 were market size. This was found to be unprofitable as the expense of shipping adult oysters was excessive.

"Morgan Oyster Company started the practice of shipping eastern oyster seed and planting them in San Francisco Bay, and this method was successfully maintained until about 1900. The prevailing opinion at the time was that the eastern oyster would not spawn or set seed in San Francisco bay because of the low temperature. However, no concerted effort was made to catch any eastern seed oysters, and as a matter of fact eastern seed oysters did set seed in small quantities on the eastern side of the bay. During the 90's an average of 100 carloads of 90 barrels each of seed oysters were shipped to San Francisco yearly.

"About 1900 some unknown factor or factors caused a radical change in the southern end of San Francisco Bay which acted unfavorably on the oyster beds. The eastern seed planted there took much longer to reach a fair size and they were thin, watery and unfit for mar-

ket. As the old-time oystermen knew little of the biological side of their business and ran it by a trial and error method, their only recourse was to look about for other bedding grounds. They decided to try Humboldt Bay.

"Humboldt Bay had been tested for eastern oysters by the U. S. Bureau of Fisheries, which in 1896 planted 25 barrels of 3 and 4 year old easterns from Princess Bay and East River, New York. The returns of this plant were negative. About 1910, three men—Louis Hegburg, Ivan Berggren and Olaf Thoresen—established small beds of natives in the northern end of the bay and carried on the business on a small scale. They sold their holdings to the Morgan Oyster Company in 1911 and that company immediately shipped in larger quantities of eastern oysters only to find that the local conditions were unfavorable as the U. S. Bureau of Fisheries had already demonstrated. By 1912 they had lost \$90,000 on the venture and abandoned their holdings in the bay.

"In 1911 while the Morgan Company were taking out their oysters as fast as the market conditions allowed, Mr. Louis Eaton, now a member of the Consolidated Oyster Company, planted 250,000 adult oysters in south Humboldt Bay, where conditions are a little different from those prevailing in the northern end of the bay. However, comparatively few of these

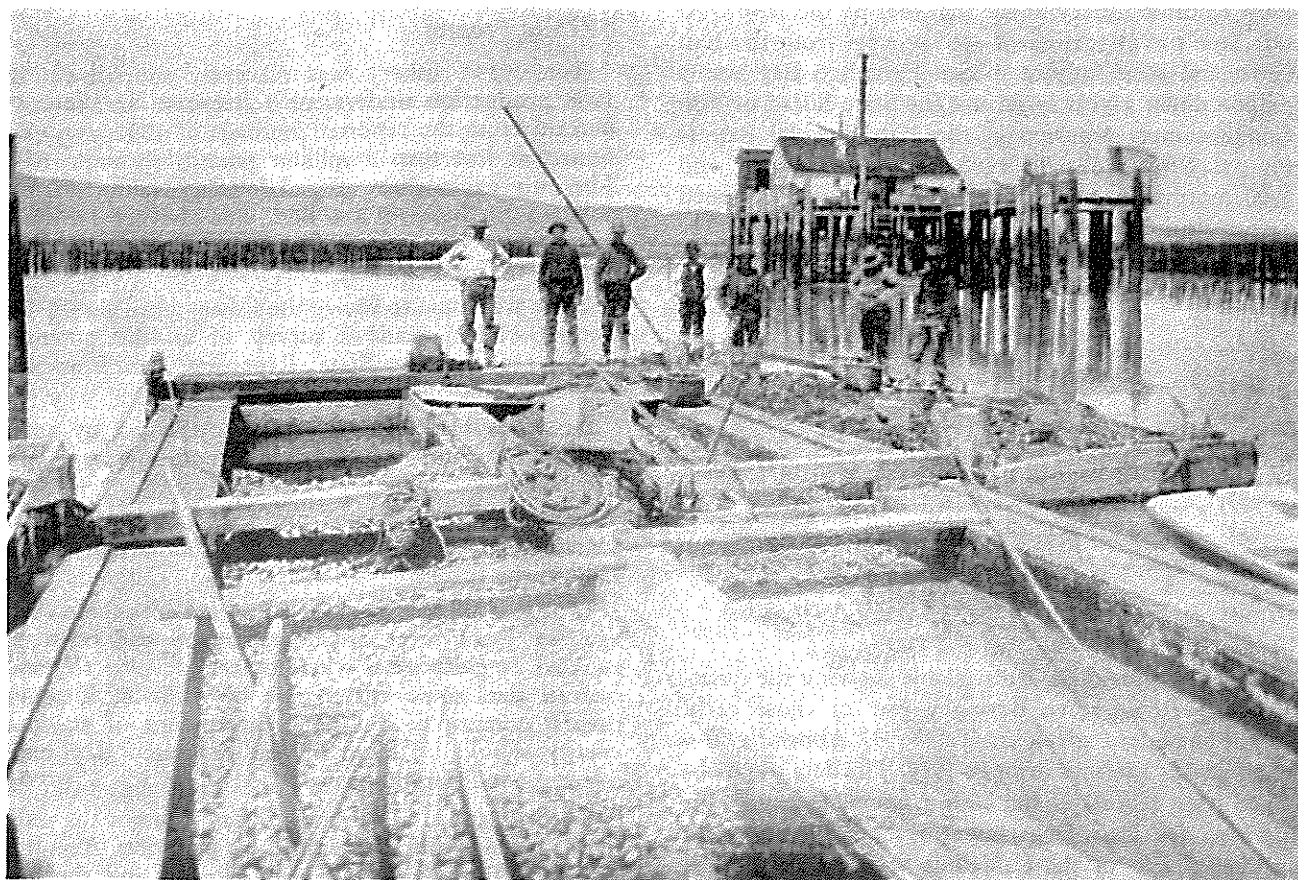
oysters were ever recovered. Humboldt Bay was given up by the oystermen and no attempt was made to do anything more there until 1932.

"Oyster planting in Tomales Bay started at about the same time as that in San Francisco Bay. At Miller-ton, on the eastern side of the bay, 17 carloads of eastern oysters were laid out by Weinard and Terry, in 1875. They simply held them there and sold as the market permitted until all were disposed of. Easterns were again planted in 1907 by Eli Gordon, who staked several small beds. Gordon later sold his holding to J. McNab and G. Smith, who in turn sold to the Pacific Coast Oyster Company, which still owns the beds and holds eastern and Olympia oysters there. The Consolidated Oyster Company put in a small bed at Blakes Landing in 1917 which is now abandoned."

Townsend (1893) mentions that the beds in Oakland and Alameda Creeks were abandoned because of sewage and traffic on the bay. At the time, he reported the Dumbarton beds as being the best in the Bay. According to him the Moraghan beds occupied 1,100 acres. Those of the Morgan Oyster Company, according to a biennial report of the State Board of Fish Commissioners, were estimated at 1,500 to 2,000 acres at that time.

It is interesting to note the value of oyster lands during this period. The information is from Townsend's report. "These lands [the tidelands of San Francisco Bay], surveyed and sold by the State at \$1.25 per acre, have gradually passed into the hands of the larger oyster companies. This is especially true of the extensive flats in the southern part of the Bay, most

FIGURE 35. Large double float with scows, tongs, baskets and other features of the oyster fishery of 1890. M. B. Moraghan Establishment. Photo credit. Report U.S. Commission of Fish and Fisheries, 1890-1891.





available for the present system of laying out oysters. . . . The Tide Land and Water Front Company of San Francisco are proprietors of the tidelands to a considerable extent and offer them for sale at the uniform price of \$25 per acre."

Quoting Mr. Moraghan of the oyster company by that name, Townsend continues, "The price depends upon the location, the kind of bottom, whether mud, shell, or sand, etc., and more than all, upon the improvement or amount of labor bestowed on the land. We have some beds that are worth fully \$1,000 per acre to us, as we have been improving and working upon them for the past ten years in bringing them to their present condition. Unimproved tide land, such as is used in the Californian method of bedding oysters, is very cheap, being worth \$10 per acre, and such lands can be had adjacent to the best inclosed beds for \$20 per acre."

The oyster industry thrived and became the single most valuable fishery in the state during the 1890's. At this time the importing of seed oysters from the East Coast and their culture in San Francisco Bay was a million dollar a year business. The State Board of Fish Commissioners reported in the 17th Biennial Report for the years 1901 and 1902 that between 1887 and 1900 more than 11,000 tons of eastern yearling seed oysters had been brought to San Francisco Bay for further growth. Wilcox (1895) provides the following data on the amount of seed oysters shipped to San Francisco:

	<i>Pounds</i>
1887 .....	1,562,000
1888 .....	1,128,000
1889 .....	1,007,000
1890 .....	1,559,000
1891 .....	3,273,000
1892 .....	2,123,000
1893 .....	1,607,000
1894 .....	1,332,000
1895 .....	1,680,000

Fortunately, records are available showing the quantity of oysters grown during a few of those early years. These are given in Table 33. Appendix B-4 shows oyster landings prior to 1918. The data were obtained from reports of the U. S. Commissioner of Fish and Fisheries, U. S. Department of Commerce and the biennial reports of the California State Board of Fish Commissioners. The oyster production figures prior to 1915 are confusing because of frequent contradictions in the early reports. As shown in Table 33, two sets of figures are available for most years, thus making it almost impossible to determine which is correct. While such discrepancies may exist, the amounts are of similar magnitude and it must be assumed therefore that the yield was on the general order of the figures cited.

TABLE 33

### EASTERN OYSTER PRODUCTION IN SAN FRANCISCO BAY PRIOR TO 1915

Year	Quantity (pounds)	Value
1880 .....	750,000	.....
1888 <sup>1</sup> .....	9,100,100 <sup>2</sup>	.....
1889 .....	12,369,000-10,500,000 <sup>2</sup>	\$571,525
1890 .....	12,829,500-10,592,750 <sup>2</sup>	592,137
1891 .....	13,387,800-11,069,100 <sup>2</sup>	618,455
1892 .....	15,098,700-12,505,150 <sup>2</sup>	698,257
1895 .....	14,975,682	.....
1899 .....	2,940,000-28,800,000 <sup>2</sup>	.....
1904 .....	1,320,000	.....
1908 .....	729,000	.....

<sup>1</sup> Includes 910,000 pounds native oysters.

<sup>2</sup> Poundage estimated from bushels, using 70 pounds per bushel.

<sup>3</sup> It is thought a typographical error is involved in this estimate, in which case the estimate would be 2,880,000 pounds and thus be in agreement with the other estimate for the same year.

### 1915 to Present

The oyster fishery was relatively short-lived. By 1908 production underwent a decrease of about 95 percent from the reported landings of 1892, and continued at less than a million pounds through 1936. The only explanation offered for the decline was the polluted condition of the Bay. The choicest locations in the Bay were heavily contaminated, resulting in oysters of poor quality.

Little was done to revive the fishery until the 1930's. Bonnot (1935) made a survey of all the potential oyster areas of the State. Regarding San Francisco Bay, he states:

"In some places development is affected by some unknown factors and the full grown oyster is not marketable."

"Recent ventures have not proved to be marked successes and it is probable that other areas will be used in the future."

"Portions of San Francisco Bay are free from sewage but great areas are contaminated and must be avoided. In clean areas where oysters develop to commercial size, some effort may be made to improve natural conditions, but no great amount of time or energy should be spent in San Francisco Bay until sanitary conditions improve."

Unfortunately, San Francisco Bay was not the only oyster ground thus condemned by pollution. Alamitos and San Diego bays, Anaheim Slough, and the Tia Juana River Estuary were all discounted as oyster growing locations because of one type of pollution or the other. Oil was the principal polluting agent at the time in the southern locations, except for San Diego Bay which received large quantities of raw domestic sewage.

The Department (then Division) of Fish and Game, and the U. S. Bureau of Fisheries entered into a co-

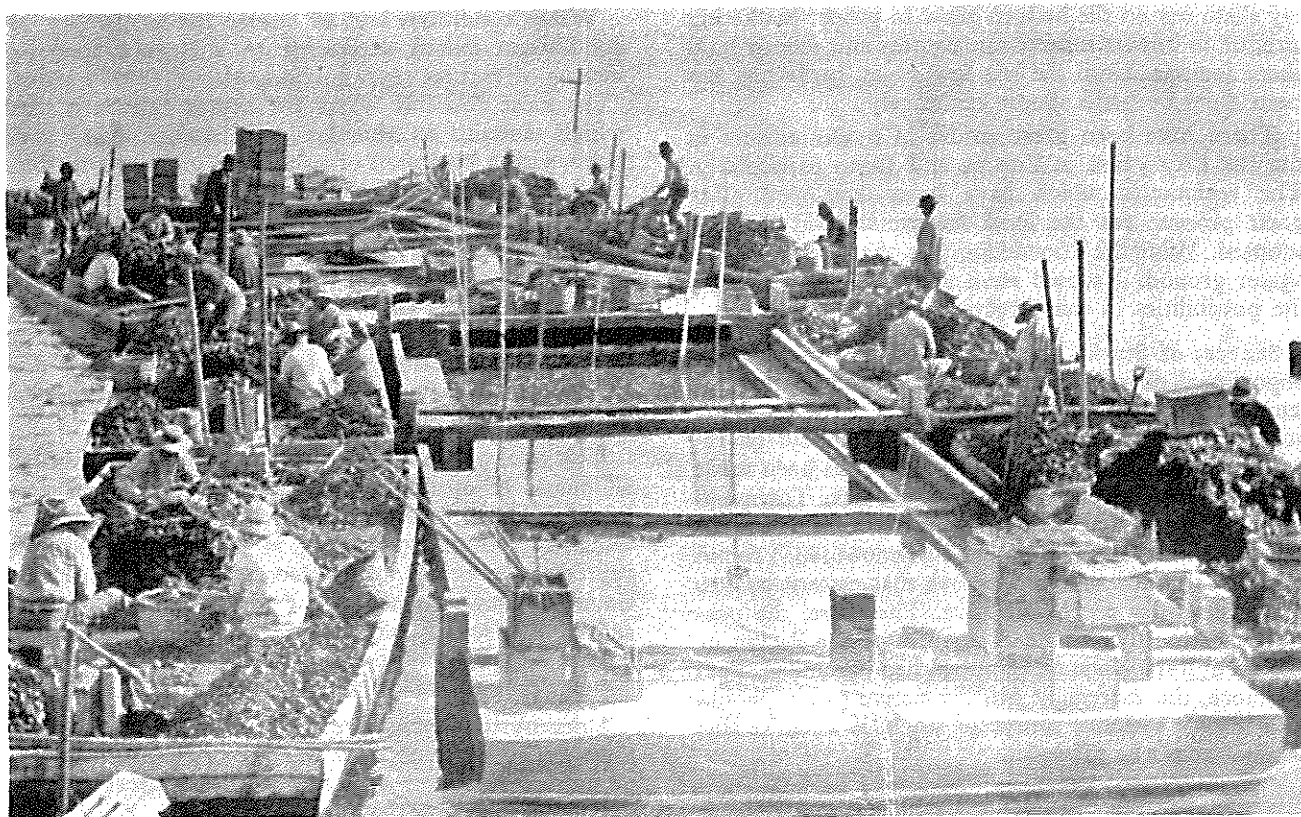


FIGURE 36. Culling oysters 1889-1891 Morgan Oyster Company, Millbrae. Photo credit. Report U.S. Commission of Fish and Fisheries, 1889-1891.

operative program in the 1930's to promote the development of the oyster potential on this coast. The program, which involved a series of surveys and research, provided much of the present knowledge about oyster culture in this State.

The program successfully stimulated the interest of private companies. The Pacific oyster (*Crassostrea gigas*) was imported from Japan in 1931 and beds were established in Drakes, Tomales, and Morro bays. Special efforts were directed toward the cultivation of the native oyster in Humboldt Bay in an attempt to offer a product which would compete with the Olympia or Willapa Bay oyster, which is the same species, grown in Washington.

The results of the program were positive and the state-wide oyster landings began to increase. San Francisco Bay, however, continued to decline as an oyster ground. Only one oyster company persisted on the Bay as late as 1937. The San Francisco Area, nevertheless, up to this time, remained the State's leading oyster producer chiefly because of new beds in Bodega Lagoon, Tomales Bay and Drakes Estero. By 1941 total production in the State reached almost 2 million pounds, mostly Pacific oysters. At this point the war interfered with the importation of seed oysters from Japan and the landings steadily decreased to 272,000 pounds by 1946.

At the cessation of hostilities oyster culture was resumed and imports were again made from Japan. Production gained momentum, until by 1956 over 6 million pounds of oysters were harvested in the State.

Humboldt and Morro bays are now the leading oyster grounds, the former being the largest producer. Of the 6 million pounds harvested in 1956, the San Francisco Area contributed slightly more than 6 percent. Landings for both the Bay Area and those of the entire State are given in Appendix B-2 from 1916 through 1958. Figure 20 compares the State and Bay Area Landings.

There does not exist an oyster sport fishery, as such, in California, although a small quantity of native oysters are taken by sportsmen. The other species have not yet distributed themselves and therefore are found only on cultivated beds.

### Oyster Culture

**General.** Oyster culture necessarily varies, according to the species grown and local conditions. Outside of these variables, there are basic differences in cultural and harvesting techniques. In California, in the past, only the crudest methods have been employed. The practice generally has been to import seed oysters and

lay them out on the beds to grow to proper marketing size, or to import market-size oysters and merely hold them for sale. Until the last few years, harvesting has been done by hand almost exclusively.

There have been great strides in oyster culture in the last fifty years, in Europe and Japan particularly. The techniques which have been developed offer great promise for the local fisheries should they be adopted. With the knowledge that the Bay is proven oyster ground, it would seem worth while to explore the possibilities in this direction.

**Sources of Stock.** Present knowledge dictates the importation of seed oyster for cultural purposes, since temperature conditions do not appear satisfactory on our coast for natural reproduction. It should be reiterated however that no special effort has been made to collect the spat of imported varieties. Townsend (1893), who examined the Bay to determine the extent of natural reproduction, and Bonnot (1935) found evidence that led them to believe that eastern oysters did successfully reproduce here. Therefore, the possibility of locally produced stock of either Pacific or eastern oysters is not to be altogether precluded. Furthermore, the extremely prolific native oyster would be a readily available source of stock, if a marketable product could be produced.

There is some advantage, however, to importing seed oyster rather than using locally spawned stock. Where natural reproduction occurs, spat usually become crowded on the available cultch and requires culling. This expensive process would be negated in the case of seed imports, which it might be added, have been easily obtained except for war years.

According to Dr. Harold Orcutt, shellfish expert of the Department of Fish and Game, Pacific oysters appear to be best suited for cultural purposes in the Bay, although the eastern oyster has been successfully grown in the past. The Pacific oyster attains a large size and is preferred for commercial outlets, while the eastern is reported as being the tastier and preferred for domestic use and as a special purpose oyster.

Under favorable conditions about 20 to 25 cases of seed oysters (16,000 to 50,000 per case) are laid out per acre. This amount when harvested should yield 20 to 40 gallons of shucked oysters (approximately 100 oysters per gallon).

**Conditions for Oyster Culture.** The primary consideration in oyster culture of course, is water quality. The need for sanitary conditions is imperative both from cultural and public health viewpoints. At the present time, for instance, public health agencies have prohibited the sale or culture of oysters for human consumption in many sections of the Bay. Good water quality is also necessary for proper growth and conditioning of a marketable product. Under adverse conditions oysters become flaccid and unacceptable to the consumer.

Water conditions and of course the availability of good clean cultch determine to a large extent the success of natural reproduction. Moore (1897) states, "The most desirable water for oyster culture is that which contains an abundance of minute living particles with a minimum of suspended inorganic matter. Such waters must be free from slime or sediment. Any substance which forms a film on spat collectors is detrimental to oyster culture." If collectors are used, precautions should be taken to see that they are set out at the proper time. They must be set out when the spat are abundant, and remain sufficiently long to assure a good quantity of larvae. But they must not be exposed so long beforehand as to acquire a film to which the spat cannot attach.

The tidal prism is apparently a requirement during all phases of oyster culture. The constant oscillation of tidal waters is necessary to disseminate the reproductive products and larvae in areas where natural reproduction occurs, to oxygenate the water, and continually renew the supply of food organisms. Tidal action also scours and cleans the spat collectors or cultch and prevents the settling of sediment and subsequent smothering of the young oysters.

Since oysters become sedentary after the larvae set, they are highly susceptible to the vagaries of weather, pollution, predation and any of the sources of exploitation to which they are exposed.

The diet of oysters consists of the great diversity of microscopic and planktonic organisms common to their environment, among which bacteria, diatoms, protozoa, microcrustacea and algae are the most important. A stream of water is constantly pumped through the mantle cavity, from which these minute organisms are strained. This same stream of water also serves the respiratory processes, bringing oxygen and carrying away carbon dioxide. "An adult eastern oyster will pump from two to seven gallons of water per hour and if not exposed at low tide will feed more than 22 hours out of every 24." Fitch (1953).

Another consideration in cultural operations is the prevention of depredation by other organisms. In the Bay Area oysters have a number of natural enemies. Chief among these are bat rays, sharks, several varieties of fish, and oyster drills. Of the latter, two species were accidentally introduced with oyster shipments. *Urosalpinx cinerea* and *Ocenebra japonica*, eastern and Japanese oyster drills respectively, are introduced species while *Thais lamellosa* is a native species. Starfish are one of the greatest threats in some areas, but do not present a problem locally.

Good success was formerly obtained with stake or wire fencing to exclude sharks and bat rays and this method could be employed again. Depredations by bat rays have been particularly serious. Fortunately, other



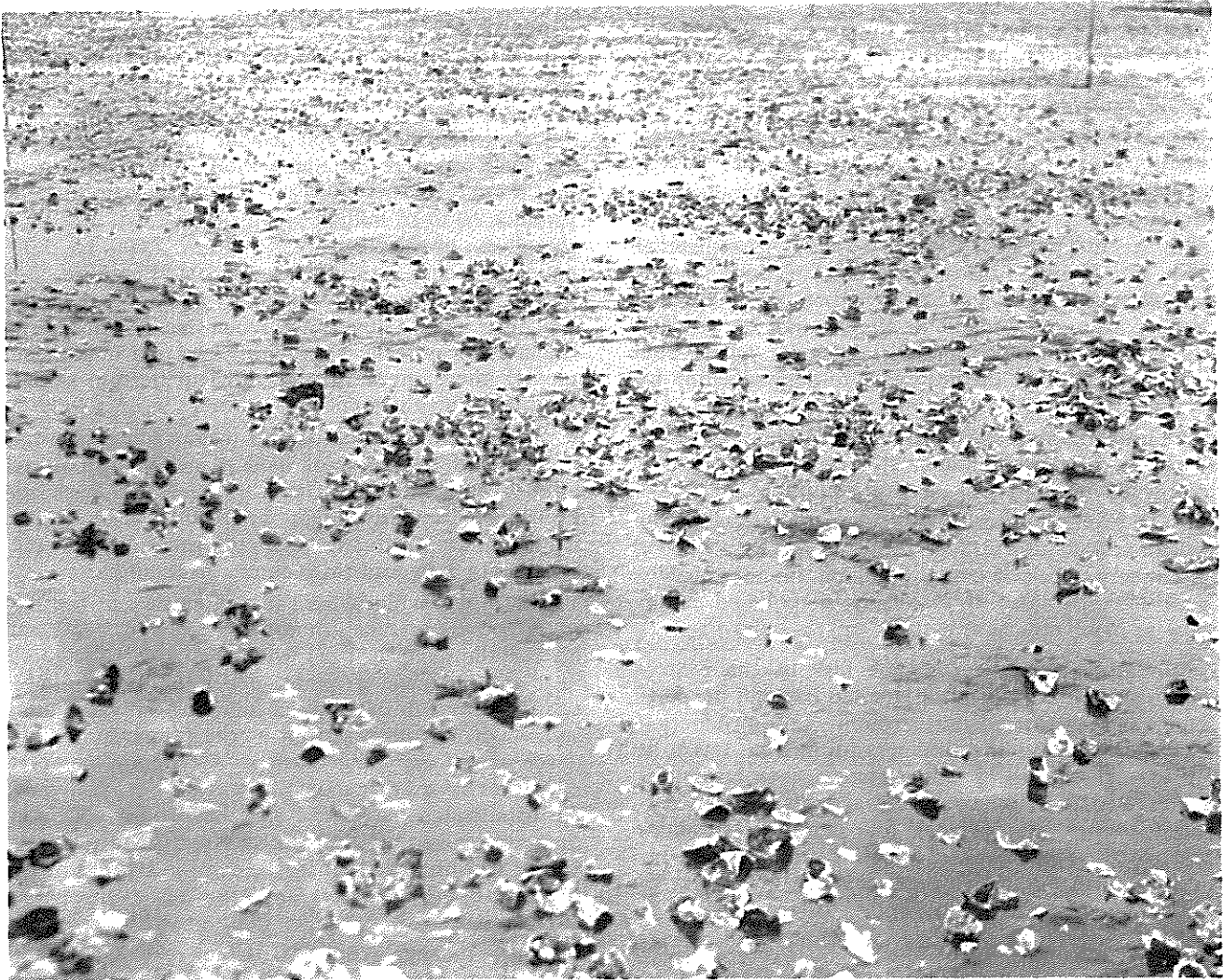


FIGURE 37. Freshly set out Pacific oyster seed on shell. D. F & G. photo by H. G. Orcutt, Jan. 11, 1956.

fish are not a serious problem; they would be almost impossible to exclude.

Oyster drills would undoubtedly cause the greatest losses unless special precautions were taken to protect against them. Presently each shipment of imported oysters is inspected and infested lots are not permitted to be planted. The predations of the drill and starfish both have been largely disposed of in some areas (foreign countries) by the adoption of modern cultural techniques in which the oysters are grown in racks or trays suspended above the bottom. Since both pests are strictly bottom forms, they are thus excluded.

**Potential for Oyster Culture in the Bay Area.** Knowing most of the estuarine waters of the Bay Area are capable of producing oysters and being supplied with quantitative data from previous production records, it is not too difficult to imagine that an oyster fishery of exceptional proportions could be developed here.

There is an unfailing market for oysters and they usually command an excellent price. The quantity grown in California in past years fell far short of the demand and much of the supply had to be shipped in from areas to the north.

Since the end of World War II and the resumption of trade with Japan, Pacific seed oysters have again been imported and highly successful fisheries have been developed in Humboldt and Morro bays and to a lesser extent in the smaller bays in the San Francisco Area. These, however, do not satisfy the present market demand. The apparent solution would seem to lie in an expansion of the industry and; as a matter of fact oyster growers have already shown renewed interest in some of the local oyster lands for the purpose of establishing commercial beds. Some lands have already been allotted to oyster concerns by the Fish and Game Commission for cultural purposes.

These allotments are made to qualified interests who agree to develop the lands for oyster production purposes. A small charge is made for the lease of the lands which the operator is required to develop at a specified rate. No allotments can be made on good natural clam beds.

The major drawback to expansion of the industry in the Bay appears to be water quality. Quoting from the 44th biennial report (1954-56) of the Department of Fish and Game: "Many thousands of acres of the largest bays—San Diego, San Francisco, San Pablo and large portions of Humboldt Bay—cannot be certified by the Department of Public Health for oyster production because of the possibility of contamination by sewage.

"This boom in shellfish production is now limited to areas presently in production and no further expansion is possible under present physical conditions.

"The oyster industry in San Francisco Bay was at its height around the turn of the century. It reached a [secondary] peak of over 1.5 million pounds annually by 1911, then faded away because of polluted conditions of much otherwise usable area."

**Production Estimates.** Some idea of the oyster-producing capacity of San Francisco Bay and the adjacent waters can be obtained from previous production records. Recalling the landings during the 1890's, it was seen that 10 to 15 million pounds were produced annually on a few thousand acres of beds. It is conceivable therefore, that a several fold increase in production could occur simply through a proportionate increase in area put under oyster culture. Reference to

Table 34, which gives the surface acreage of the principal bodies of water in the Bay Area, indicates roughly 190,000 surface acres (inclusive of restricted areas) with some degree of potential as oyster grounds.

Data from 1890 to 1900 provide a rough estimate of the yield per acre for that period. The available evidence indicates that 3,000 to 4,000 acres were used to produce 10 to 15 million pounds of oysters. The yield therefore, could have varied from 2,500 to 5,000 pounds per acre. At the latter rate 10,000 acres of good oyster ground could produce 50 million pounds per year. Even at the lower rate, which incidentally, seems the most reasonable considering the techniques employed, there appears to be sufficient bottom land to produce twice this amount.

As further evidence of the oyster potential some examples of the result of modern methods of oyster culture, as practiced in Japan, France, Denmark and Holland particularly, might be cited. The techniques employed are much advanced over those now in practice in this state and this country generally.

Dr. Coste revolutionized oyster culture in the Bay of Arcachon, France (Smith and Chapin, 1954) and his techniques have been widely adopted elsewhere. Spat are collected on pieces of tile or other suitable substance, which has been coated with lime and sand, and which has been set out at the proper time. The development and abundance of larvae are observed closely to assure that the collectors are not set out too far in advance. After the spat have been collected, they are broken off and placed in wire covered trays which are suspended on legs above the bottom of the Bay. Finally the oysters are moved to "claires" or fattening beds to complete their growth.

In this manner about 500 million edible oysters a year are produced in the 37,000 acre Bay of Arcachon, for an approximate yield of 13,500 oysters per acre.

Intensive culture in Japan and Holland has resulted in the production of about 6,000 pounds per acre. Production in Holland has been increased from ½ to 2 million oysters per year under natural conditions to 30 to 40 million superior oysters under culture.

**Status of Bay Area Sites.** A very brief description and statement of the present status of Bay Area oyster sites and the potential of various waters in the Bay Area for oyster culture follows. Table 35 provides information on present oyster allotments and private beds.

*San Pablo Bay:* Pollution appears to be less severe here than in any other part of San Francisco Bay. Most of the Bay appears physically suitable for growing oysters. No portion is too deep, and the bottom appears to be generally satisfactory. The concern of Clayton McNeil had an allotment of 3,000 acres in this Bay for oyster cultural purposes, but abandoned it after a small initial plant proved unsuccessful. The

TABLE 34  
SURFACE ACREAGE OF SELECTED WATERS  
IN THE BAY AREA

Location	Acreage	Potential Oyster Grounds <sup>1</sup>
South Bay .....	141,100	100,000
North Bay .....	40,300	5,000
San Pablo Bay .....	71,400	70,000
Subtotal .....	252,800	175,000
Carquinez Strait .....	4,500	
Suisun Bay .....	17,600	
Upper Suisun Bay .....	7,800	
Subtotal .....	29,900	
Tomales Bay .....	9,600 (est.)	9,600
Bodega Bay .....	700 (est.)	700
Bolinas Bay .....	500 (est.)	500
Drakes Estero .....	3,000 (est.)	3,000
Subtotal .....	13,800	13,800
Grand Total .....	296,500	188,800

<sup>1</sup> These figures are rough estimates based on the depth and type of bottom. No attempt has been made to exclude public clamming (or restricted) areas in the estimates.

TABLE 35

## CURRENT OYSTER ALLOTMENTS AND PRIVATE OYSTER BEDS IN THE BAY AREA

Location	Ownership	Acreage	Name of Concern
San Pablo Bay.....	State Allotment #60	3,000	Clayton McNeil
Tomales Bay.....	State Allotment #1	387	Coast Oyster Company
Tomales Bay.....	State Allotment #52	88	Coast Oyster Company
Tomales Bay.....	State Allotment #34	120	Henry Jensen
Tomales Bay.....	Private	5*	Spenger
Tomales Bay.....	Private	10*	Tomales Bay Oyster Co.
Drakes Estero.....	State Allotment #2	1,165	Coast Oyster Company
Bolinas Lagoon.....	State Allotment #57	240	Coast Oyster Company
Total Acreage.....		5,015	

\* Estimated.

Coast Oyster Company has also expressed an interest in San Pablo Bay.

Several factors appear to be affecting the development of San Pablo Bay for oyster purposes. Apparently there are few interests willing to invest the capital required to establish the industry on unproven ground, and furthermore, certain areas are restricted by the Department of Public Health. Industrial pollution is serious in some areas.

*South San Francisco Bay:* At the present time no oyster operations are conducted in the South Bay due to the public health quarantine. The Department of Fish and Game is experimenting with small plants in the vicinity of Palo Alto to observe the growth and condition of oysters planted in this area. The entire South Bay is potentially valuable oyster ground, perhaps the finest in the State. It is proven ground and the only serious factors limiting its use are pollution and public health restrictions.

*North San Francisco Bay:* Oysters are not grown here at the present time. The North Bay does not appear to have the potential of either the South Bay or San Pablo Bay. Some areas are rather deep for oyster purposes. However, portions with mud bottoms, and the smaller coves and bays along each side, are possibilities. Richardson's Bay, for example, was used as an oyster ground before 1900.

*Tomales Bay:* This bay has extensive shallow areas well suited to oyster culture. The east side of the bay is most suited to the purpose. The Tomales Bay Oyster Company and the Spenger Oyster Company are currently growing oysters here on private beds. A total of 595 acres has also been allotted by the Fish and Game Commission to oyster interests. This Bay produces fine oysters and the potential is good. A

large portion of this Bay, being one of the most productive clam areas in the State, has been set aside as a public clamming area and cannot be allotted for other purposes. Extensive development is also limited because most of the adjacent land is in private ownership.

*Bolinas Lagoon:* This is another excellent shellfish area. Clamming is superior, but oyster culture has been limited. The Coast Oyster Company has a 240 acre allotment here and has spent two years in developing it. Although operations are still in the exploratory stage, it appears to be a promising producer. The rest of the Lagoon is set aside as a public clamming area.

*Drakes Estero:* Past experience has shown this site to be a good oyster producer. Formerly, the entire area (about 3,000 acres) was in oyster allotments. At the present time 1,165 acres along the shoreline are reserved for this purpose. The rest has been set aside as a State public clamming area. The Coast Oyster Company is active here and the oysters produced are of excellent quality, entering the trade as half shell and for other specific purposes requiring a first class product. This area can be expected to be developed to the fullest possible extent in the future.

*Bodega Bay:* Bodega Bay is rather small (about 700 acres) and oyster potential is limited. The only suitable area lies in the south end of the bay where beds formerly existed. It is chiefly a clamming area.

*Private Salt Ponds.* The use of small acreages of privately owned tidal bottom lands or salt water ponds has not been investigated in California to the writer's knowledge. On the Atlantic Coast, however, some experimental work is being done along these lines, with commercial oyster culture in mind. The U. S. Bureau of Commercial Fisheries has reported the successful setting and growth of eastern oysters in salinities varying from 15 to 27 parts per thousand.

## THE CLAM FISHERY

Much of the foregoing enthusiasm about the possibilities of oyster culture in the Bay could appropriately be applied to clams as well. However, there is little doubt that where private enterprise is concerned, efforts at clam culture would be secondary in view of the more lucrative oyster.

Bonnot (1940b) and, more recently, Fitch (1953) have described the common marine bivalves of California. Fitch, in addition, gives a brief but informative account of their habits and habitat, anatomy, locomotion, feeding, growth, reproduction, maturity and ecological relationships.

Introduced species have sustained the clam market in the Bay Area.

### Early History

The original shellfish fauna of the Bay Area was extensive, but few species could be considered of good commercial value as food products.

The more important species were the Washington, gaper, Pismo, common littleneck (formerly called rock cockles) and bent-nose clams, and sea mussels.

The most common edible species of the Bay was the bent-nose clam (*Macoma nasuta*). According to Fisher (1916) Chinese shrimp fishermen dug large quantities of them in the South Bay for the market prior to 1876. This is also the most common species found in Indian shell mounds.

The sea mussel (*Mytilus californianus*) was widespread and abundant and was in moderate demand.

Most of the common little neck clams (*Protothaca staminea*) in San Francisco markets came from Tomales Bay, where they were very abundant.

Gaper (*Schizothaerus nuttalli*) and Washington (*Saxidomus nuttalli*) clams are fairly abundant and certainly must have entered the market in some quantity, although records specifically referring to them were not located.

Pismo clams (*Tivela stultorum*) are rare in the Bay Area and probably did not contribute substantially to the early markets.

The soft-shell clam (*Mya arenaria*) is believed to have been accidentally introduced with the first oyster importations in 1869 or 1870. At any rate it soon displaced the native species in the Bay and became widely distributed over the entire region. It is an excellent food clam and formed the bulk of the clam trade in San Francisco. The mud flats of San Pablo Bay and the South Bay were particularly favorable locations.

The common bay mussel (*Mytilus edulis*) is not a native species, but is thought to have reached our coast from Europe by way of sailing vessels several hundred years ago. It contributed substantially to the shellfish catch in past years. In Europe it is cultivated extensively as a food mollusk.

The ribbed horsemussel (*Arcuatula demissa*) is another apparently accidental introduction. It was first detected in 1894. It is not a major species.

The Japanese littleneck clam (*Tapes semidecussata*) was first detected about 1931 and is believed to have been introduced with shipments of the Pacific oyster from Japan. This small clam rapidly became disseminated along the coast from San Francisco northward. They are particularly abundant in San Francisco Bay and the Delta.

Reports of the U. S. Commissioner of Fish and Fisheries indicate that between one and three million pounds of clams and mussels were taken regularly each year from 1880 to 1900. The soft-shell clam of course was the principal species but bay mussels were also taken in fair quantities. For example, Wilcox (1895) reported 487,995 pounds of mussels for 1895 and in a

later report (1901) listed the mussel landings for 1899 at 364,076 pounds. Landings prior to 1918 are given in Appendix B-4.

Bonnot (1932) provides a brief summary of some commercial clamming operations in the Bay Area from their inception to 1932:

#### South San Francisco Bay.

"*South City (near Fuller Paint Works)*: a fenced bed of about 25 acres. The bed was staked in 1890 and has been maintained ever since by a family named Maitzer. It is in fine shape at present [1932].

"*Western Pipe and Steel Plant*: This bed was fenced in 1890 by John Connell and was worked by him and later by his son. It was destroyed in 1920 by the shipyard which was built there.

"*Bayview*: A staked bed of 50 acres laid out in 1890 by Connell. It was worked until 1930, when it was abandoned due to industrial wastes which are dumped into the bay. This condition has been steadily increasing as more and more factories locate on that part of the bay.

"*Bayshore*: This bed was staked in 1925 by Connell. It was an enclosed bay of about 10 acres. It was destroyed in 1931. Connell's lease ran out and the city took over the cove and is now filling it up with refuse from the incinerator.

"*San Leandro Bay*: This bed is not fenced. It is quite large. A good many clams are dug for the market from this bed by Chinese."

#### North San Francisco Bay.

"All the beds from Sixteenth Street, Oakland, to Cosy Cove with the exception of Quong Sang's bed at Albany are merely open flats where any one can dig clams.

"*Albany*: This bed is enclosed by a very modern square-meshed wire fence on redwood posts. The fence encloses about 100 acres and there is a small house where a couple of Chinese live who act as keepers and diggers.

"*Martinez and Napa River*: I have not seen these beds. They are reported to be good. Digging on them started this year [1932]. The reports I have received all claim that clam beds so far up the river are due to the lack of fresh water and the consequent upriver push of salt water.

"*Tiburon*: There are three small beds here, all staked and owned by John Connell, who owned the beds about South City. The beds will cover about 8 acres of bottom."

**Tomales Bay.** "There is only one staked bed in Tomales. It is the largest fenced bed in the vicinity. The area enclosed is about 300 acres. It belongs to the Pacific Oyster Company and was originally intended for oysters. It is at present under lease to the Hop

Lung Clam Company. Although there are soft shell clams all over Tomales Bay, they can only be found in paying quantities inside this fence."

**Bodega Bay.** "The whole bottom of Bodega Bay is good clam ground and six or seven species are taken in commercial quantities, including the soft shell. A great many of the clams of all species are used by the local fishermen for bait. None of the bottom is fenced."

TABLE 36  
FORMER CLAM BEDS IN THE BAY AREA <sup>1</sup>

Location	Fenced or Unfenced	Acres	Started	Destroyed	Owner
South City .....	yes	25	1890	---	Maitzner
South City .....	yes	25	1890	1920	Connell
Bayview .....	yes	50	1890	1930	Connell
Bayshore .....	yes	10	1925	1931	Connell
San Leandro Bay	no	100	---	---	Public
Sixteenth Street					
Oakland .....	no	150	---	---	Public
Brooks Island ...	no	50	---	---	Public
Sobrante .....	no	100	---	---	Public
Wine Haven ...	no	100	---	---	Public
Cozy Cove .....	no	40	---	---	Public
Albany .....	yes	100	1928	---	Quong Sang
Tiburon .....	yes	3	1930	---	Connell
Tiburon .....	yes	2	1930	---	Connell
Strawberry Point	yes	3	1930	---	Connell
Tomales Bay ...	yes	300	1910	---	Pacific Coast Oyster Company
		1,058			

<sup>1</sup> Data from Bonnot 1932.

### 1915 to Present

With the initiation of the record system in 1915, accurate information on clam landings became available. But the resource had degenerated greatly by then.

Soft-shell clams remained the most important market species in the Bay and as a matter of fact comprised almost the entire catch in Area after 1915. Annual soft-shell landings are shown in Appendix B-2. They were on the order of about 100,000 to 300,000 pounds between 1916 and 1935. The species continued to decrease until they eventually dropped completely out of the commercial picture in 1949. There have been no landings reported since that time. Bay Area landings constituted virtually the entire state-wide total of soft-shell clams.

Pismo and razor clams have been omitted from this discussion since both are rare in the Bay Area. Pismo's were the most important commercial species in the State for a number of years immediately preceding 1920 but, due to pollution and excessive digging, landings dropped below those of soft-shell clams. In California, Pismo clams are found chiefly along the coast of San Luis Obispo County.

For the sake of convenience all clams and mussels other than soft-shell clams have been arbitrarily classified as miscellaneous clams in Appendix B-2. The combined landings of all species in this category rarely

FIGURE 38. Orientals digging soft-shell clams on flats of San Pablo Bay at Pinole about 1920. D. F. & G. photo presumably by F. W. Weymouth.





exceeded 100,000 pounds per year in the Bay Area between 1916 and 1935. During this period the Bay Area landings comprised about one-half of the state-wide total. In 1936 only 7,000 pounds were recorded from the San Francisco Area. Less than 500 pounds have entered the commercial catch in the last 17 years.

State-wide landings of miscellaneous clams underwent a sharp decline between 1936 and 1943 to a low of 898 pounds in the latter year.

One of the reasons for decreased clam landings throughout the State is the labor required to dig them. Populations exploited by the general public have become sparse and it simply does not pay to dig them commercially. Furthermore, the State has reserved for the public some of the better clamming locations, and these may not be exploited commercially.

### *The Present Fishery*

**Sport Fishery.** Some of the finest natural clam beds in the State are found in the Bay Area, where each year throngs of people flock to the beaches to dig them. The resource affords recreational opportunity and at the same time provides a good many people with a tasty seafood treat they might not otherwise enjoy.

Unfortunately, data on the number of diggers or the effort and money thus expended each year are unknown.

**Current Clamming Localities.** Several investigators have surveyed the California shellfish resources. Among these might be mentioned Heath (1916), and Weymouth (1920). Dr. Harold Orcutt of the Department of Fish and Game made observations of the clam resources, incidental to a recent oyster survey.

A brief summary of the principal locations and the more important species found in each follows:

**San Pablo Bay:** Formerly, this bay produced the greatest share of soft-shell clams marketed in San Francisco. They have not been exploited recently, largely because of the public health problem. Recent observations by Orcutt indicate they are still present in good numbers. The bent-nose and Japanese littleneck clams are also present. Data are not available regarding the status of the littleneck in San Pablo Bay, but they may be assumed to be there in good quantity. The Chinese operated soft-shell clam beds at Pinole until recently. Weymouth (*op. cit.*) reported that a single digger could obtain between 60 and 100 pounds on one tide here.

**South San Francisco Bay:** As in San Pablo Bay, the chief species here is the soft-shell clam. Originally the bent-nose was very abundant but was displaced by the imported soft-shell. The Japanese littleneck has presumably become well established here also. Washington and gaper clams are present but not abundant. Other species are found in limited quantities.

Domestic and industrial pollution have resulted in the complete loss of the South Bay clam fishery. The last so called "farm" operated near Bayshore. Weymouth in his report stated that many localities of San Francisco Bay were unsafe sources of food mollusks.

**North San Francisco Bay:** Except in the shallow tidal flats and bays such as Richardson Bay, clams are not particularly abundant. Clam habitat here is limited. The species present are essentially the same as in the South Bay, although more of the marine forms are found here than in the South Bay or San Pablo Bay. The bay mussel is found in good numbers attached to rocks, piles, shell, and similar substrate.

**Tomales Bay:** According to Weymouth the common littleneck clam reached its greatest abundance in Tomales Bay from where the major share for the San Francisco market was obtained. Soft-shell clams are fairly abundant and were dug commercially until recently. This is one of the better clamming areas and sport clammers take large numbers of Washington and gaper clams as well as the other species. A large area of this bay between Tom's Point and Sand Point is reserved as a public clamming ground.

**Bodega Bay:** Virtually all of this Bay may be considered good clam grounds. The principal species found here are the Washington and soft-shell clams and the gaper. It is an excellent sport clamming area.

**Bolinas Lagoon:** The accessibility of this bay makes it a popular sport clamming area. It is a good producer of gaper, Washington and littleneck clams.

**Drakes Estero:** At the present time this is one of the very finest clamming areas in the State. Clams are abundant and of fine size and quality. The principal species are Washington, gaper and soft-shell clams. Being surrounded by private land, the Estero is rather difficult of access and this is perhaps largely responsible for the present clamming quality.

**Halfmoon Bay:** Clams are not overly abundant here. Among the species taken are Pismo and Washington clams.

Most of the species just described are usually found in sheltered bays or coves. In contrast to them, many shellfish are found along the outer coast attached to the rocks of exposed reefs, as for instance the sea mussel (*Mytilus californianus*) and some of the boring clams which are so situated that they are constantly lashed by the full force of the surf. Others like the Pismo, razor and white sand clam are found burrowed in the sand along the ocean beaches.

**Special Species.** Several species deserve special mention because of their importance to sport diggers, or to the commercial industry, or because of their abundance. Insofar as possible, information is provided on the location of the better known beds.

*Washington Clam:* The Washington is one of the more important species to sport clam diggers and is especially esteemed as a food mollusk. According to Weymouth "The localities in which they are most markedly abundant are: Humboldt Bay, Crescent City Beach, Bodega Bay, Wilson's Creek, Tomales Bay, Bolinas Bay, and Drakes Estero." Morro Bay is an equally important source of Washington clams. "In Bodega Bay the beds lie in the middle ground exposed by the tides, and along the western shore. In Tomales Bay the beds are neither extensive nor utilized commercially. In Bolinas Bay they are nearly gone, due, it is said, to the deposition of sand. Judging from the fact that at one time the Indians came annually to camp at Tomales Bay in order to gather the Washington clam, they must have been far more abundant then, than at the time [1919] of the survey."

"It is improbable that any further development of an industry based on this clam is to be expected. It is less hardy and of slower growth than *Mya* [soft-shell] and hence less able to withstand excessive fishing."

The shells of this species were formerly used as money among the coast Indians. A heavy valve without discolorations was worth about fifty cents around 1900.

*Littleneck Clam:* In California the common little-neck clam reaches its greatest abundance in bays such as Humboldt, Bodega and especially Tomales, according to Weymouth. At the time of his survey [1919] he stated that in Bodega Bay it was of sufficient importance to warrant digging commercially for shipment to the San Francisco markets. They are most abundant on the northwestern side of Bodega Bay.

Good beds in Tomales Bay are located on the gravel and boulder beaches.

Quoting Weymouth, "On the northern side of the Bay the best beds are between Marshals and Arroyo San Antonio; on the southern side they lay opposite these and for two miles towards the head of the Bay from Inverness . . ."

*Bent-nose Clam:* This species is of particular interest because it is the most common and widely distributed species in the State. It is a hardy species, common to sheltered bays and sloughs. It tolerates a great range of water and bottom conditions, but is not common on sand or gravel beaches or in situations where it is exposed to the surf. Weymouth states "It is a hardy species, flourishing under conditions speedily fatal to many other forms."

Although the bent-nose has been used as a food mollusk, they are generally overlooked by most clammers. These are the most common shells found in the Indian shell mounds, indicating they were an important food item to the Indians.

*Gaper:* With the exception of the geoduck, this is the largest species of clam in California. It may reach a

length of eight inches and weigh up to four pounds. They are found in a variety of habitats, except in areas of low salinity, and are fairly abundant at a good many locations along the California coast. In the Bay Area, particularly good locations include Bodega Bay, where they are found on the middle tidelands near the channels; Tomales Bay, between Sand Point and Tom's Point and in association with littleneck clams on the beaches; in Drake's Estero they are found along the eastern spit. Beds are also located along the coast between Bodega and Tomales Bay. The gaper is one of the most important species taken by clammers. It is not particularly favored as a food item in comparison to some of the other species; nevertheless, diggers exploit the available beds fully.

*Soft-Shell Clam:* The soft-shell is one of the better known food clams. It is widely distributed in all favorable estuaries, bays, and river mouths north of San Francisco. San Francisco Bay, however, is the center of abundance because of the large expanse of favorable habitat. It prefers sheltered bays free from heavy wave action.

Important beds in the Bay area, other than in the Bay itself, are located in Bodega Bay along the eastern shore and the northern end of the western shore, and in Tomales Bay, near the head of the Bay and along the northeastern shore. Beds of lesser importance are found in Drakes Estero and the Estero del Americano.

The beds in Bodega and Tomales Bay offer fair results to sport diggers but would not withstand commercial exploitation. Drake's Estero, being encompassed by private land, is not easily accessible to sport diggers.

The soft-shell clam offers the greatest possibility for cultivation, here as on the Atlantic Coast. The species is hardy, fast growing, and tolerant of variable salinity. San Francisco Bay with its extensive mud flats could support a fair industry were it not for polluted conditions. At the present time, the cost of labor and the initial capital required to fence out predacious sharks and stingrays, are additional factors discouraging clam culture.

*Japanese Littleneck Clam:* Special mention should be made of this clam because it has become abundantly distributed in San Francisco Bay. It will tolerate very low salinity and a variety of bottoms. It attains a length of about 3 inches and is reported to be an excellent food clam. They are eagerly dug by Bay Area clam enthusiasts.

*Sea Mussel:* The California sea mussel is taken in fair quantities by clammers. Since it is the species most commonly associated with mussel poisoning, it deserves brief mention in this connection.

During the summer months, June to September, the tiny dinoflagellate *Gonyaulax* becomes very abundant in the ocean and forms a substantial part of the diet of clams and mussels. Contaminated shell fish become

toxic and if eaten by man may cause serious illness or may even be fatal. The poison causes paralysis, first of the extremities, and then the respiratory muscles. Death, if it occurs is usually due to respiratory failure. The Department of Public Health issues warnings at the appropriate time each year. Sport clam diggers should watch for and heed these warnings.

### THE ABALONE FISHERY

Abalones are large gastropods, distant relatives of land snails, which inhabit the rocky beaches of the outer coast from high tide to considerable depths. They are found on rocks, to which they cling with great tenacity by means of their broad muscular foot. They belong to the genus *Haliotis*.

#### Early History

The coastal Indians of California utilized abalones for food and prized their beautiful nacre shells; pieces of which were used as money. At the time the Spaniards were seeking the valuable sea otter, they found the Indians willing to barter two pelts for a single shell.

The white man at first neglected this resource and left it to the Chinese, who took them in tremendous quantities between 1864 and 1915. Although some were consumed locally, the bulk was dried and shipped to the Orient. Californians became aroused about 1900 and obtained legislation in 1913 which prohibited the drying and exportation of abalones. After these legislative restrictions, the Chinese passed out of the abalone industry, but by then Southern California beds were pretty well depleted.

The Japanese entered the abalone fishery about 1900 and worked the waters off Monterey and San Luis Obispo counties principally. The introduction of the diving suit by them made it possible to fish in the deeper unexploited waters. They monopolized the fishery until World War II.

The abundance of abalone shells led to a short-lived but prosperous industry in the late 1800's. It is from these mollusks that much of the supply of nacre or mother-of-pearl was obtained for the manufacture of souvenirs, curios, jewelry and buttons. The industry faded shortly after 1915. During the "seventies" an abalone shell was worth about twice as much as the meat.

The first abalone cannery was established at Cayucos in 1905. By 1917 the number had grown to five but was reduced to three in 1921. The last cannery was abandoned in 1931.

Caucasians entered the fishery seriously about 1930, confining their efforts to Morro Bay and vicinity.

Since 1930 abalones have been sold chiefly as a sliced frozen product with a limited amount reaching local markets in the fresh state. They are generally considered a luxury item.

Although abalones are found all along the coast they are not equally abundant in all areas. Red abalones, one of the most important commercial species, are taken in greatest quantities off San Luis Obispo County. North of Point Lobos, Monterey County, abalones in general become decreasingly abundant.

Current regulations require commercial interests to fish in depths of 20 feet or more and at least 150 feet offshore, reserving the shallower waters for sport purposes.

#### The Commercial Fishery

The paucity of data prior to 1915 does not permit proper evaluation of the early fishery. In 1879, 787,600 pounds of abalone worth \$38,880 were recorded. In the same year 3,383,500 pounds of shell brought \$88,825. The 2,600,000 pounds recorded for 1888 was the largest quantity noted by the author.

Catch records since 1916 are complete and are listed in Appendix B-2. Landings at San Francisco have been very erratic, with little or none recorded from the years 1918 to 1934 and again between 1937 and 1942. In the intervening years the largest quantity recorded was 33,667 pounds in 1936. Since 1943 the landings have been highly variable. In 1945 for instance, 390,310 pounds were taken, the modern high for the Area, yet in 1947 none were recorded. The landings generally range from 10,000 to 40,000 pounds.

Changing legislation is partially responsible for the erratic nature of the San Francisco landings. The coast was closed all along the Bay Area counties in some years, open in other years, and for the past several years only the area south of Point Lobos, San Francisco County, including the Farallones, has been open. Abalones are not abundant enough to sustain a major commercial fishery north of Monterey County.

The state-wide landings reached a million pounds shortly after 1915, and up until World War II averaged about 2 million pounds annually. The war and absence of divers brought about the lowest catch ever recorded (164,462 pounds) in 1942. By 1945 landings were again well over 2 million pounds and since 1950 have repeatedly exceeded 4 million pounds of which 1.5 to 2.1 million pounds are pink abalones from Southern California. Average catch for the State during the 1916-55 period was 2,430,000 pounds.

The contribution of the Bay Area to the State-wide abalone catch is minor.



FIGURE 39. Sportsmen searching for abalones along Marin County shoreline. Photo courtesy Marin County Sportsmen's Association.

### The Sport Fishery

Abalones are sought intensively by many people in the Bay Area. There is a long open season each year and on a series of minus tides scores of people can be found searching the rocks for them. Most of the easily accessible locations have been pretty well depleted, but fair quantities still exist in the relatively inaccessible areas north of the Golden Gate.

Particularly popular areas along the Bay Area coast include Pillar Point, Montara, and the Marin County coast. In some localities north of Stinson Beach abalone fishing is excellent for the fortunate few who are able to gain access.

### General Information

There have been many technical and popular reports written on abalones. Edwards (1913) gave a brief account of the fishery of that time and some historical information. Croker (1931), treated the same subjects but more extensively. Thompson (1920), described the abalones of Northern California and their distributions. Bonnot (1948), in more detail described seven of the eight species, listed their distribution, and also touched briefly on their life history.

Of the eight species found in California four are represented in the ocean off Bay Area counties. The red abalone (*Haliotis rufescens*) is the principal species in both the sport and commercial fisheries. The black abalone (*Haliotis cracherodii*) may be fairly common in some locations, while the green (*Haliotis wallalensis*) and the Japanese (*Haliotis kamtschatkana*) abalones must be considered scarce.

Abalones occupy the intertidal zone from high water to a depth of about 300 feet, though maximum concentrations are found in depths of 25 to 40 feet. Cox (1958) in his investigation disclosed that abalones are particularly sedentary. Tagged animals have been found in the same areas in which they were released two to three years previous. They do not appear to move from one depth to another, although short lateral movements (parallel to shoreline) may occur. None released in water over 20 feet deep have ever been recovered in shallower water.

Spawning takes place in the spring and summer. There is a free floating stage which is estimated to last from 8 to 10 days before the spat drop to the bottom to assume the adult characteristics. Young abalone are found on the underside of rocks and in dark crevices.

It is thought they are light sensitive. The shell does not cover the mantle until they are about 4 inches in diameter, a condition which would expose them to numerous predators were they not to seek secluded locations. Growth occurs chiefly in the winter. Once they reach about 4 inches they come out into the open. Any form of confinement or artificial restraint is usually lethal in a short time.

Abalones are unable to tolerate polluted conditions. An experiment involving the exchange of unhealthy abalones in the vicinity of a sewage discharge (Los Angeles County) with healthy ones from an uncontaminated area was conducted recently by the Department of Fish and Game. As might be expected, the healthy ones, when placed near the waste discharge became diseased, while the unhealthy ones recuperated in the uncontaminated area.

### THE MARINE BORERS

Brief mention might also be accorded the marine borers, which in the past have caused immense economic losses through their destruction of wharves, pilings, docks and wooden ships.

Three species are known to occur in San Francisco Bay. The most destructive has been *Teredo navalis*, a species suspected of being accidentally introduced about 1913. *Teredo diegensis* has been detected, but at only one locality prior to 1927, when the San Francisco Bay Marine Piling Committee made its final report. Another species, *Bankia setacea*, is also very destructive of wooden marine structures.

The general extent and abundance of these pests and the destruction and subsequent economic losses caused by them is covered in detail in the above mentioned report. (Hill and Kofoed, 1927)

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